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Development of the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory

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16. ABSTRACT The paper describes the development of the 1985 National Acid Precipitation Assessment Program (NAPAP) emissions inventory. NAPAP includes the facility for research and preparation of comprehensive emission inventories. Task Group B, Man-made Sources within NAPAP, has directed the development of a 1980 inventory for anthropogenic emissions in the contiguous U.S. to support Lagrangian and Eulerian acid rain transport and deposition model development. The development of such inventories includes the formulation of emission factors for many pollutants (e.g., SO2, NOx, primary sulfate, alkaline dusts, CO, and numerous specific and/or generic volatile organic compounds). Activities to date have included the development of a historic emission inventory for SO2 and NOx within the 1900-1980 period. Present and near-term projects include a number of interrelated tasks to develop a 1985 emission inventory. A data handling system will be developed to provide the necessary spatial, temporal, and species resolution of the inventory. Planned quality assurance activities will focus on establishing a QA expert team for review of the inventory development. The 1985 inventory will be formulated to support the final testing and application of the Eulerian model.

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Precipitation	Stationary Sources	04B
Acidity	Acid Precipitation	07D
Assessments	NAPAP	14B 07B
Inventories	Manmade Emissions	15E
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The National Acid Precipitation Assessment Program has been formulated to include the facility for research and preparation of comprehensive emission inventories. Task Group B Man-Made Sources within NAPAP has directed the development of a 1980 inventory for anthropogenic emissions in the contiguous United States to support Lagrangian and Eulerian acid rain transport and deposition model development. The development of such inventories includes the formulation of emission factors for many pollutants such as SO_2, NO_x, primary sulfate, alkaline dusts, CO, and numerous specific and/or generic volatile organic compounds. Activities to date have included the development of a historic emission inventory for SO_2 and NO_x within the 1900-1980 period. Present and near-term projects include a number of interrelated tasks to develop a 1985 emission inventory. A data handling system will be developed to provide the necessary spatial, temporal, and species resolution of the inventory. Planned quality assurance activities will focus on establishing a QA expert team for review of the inventory development. The 1985 inventory will be formulated to support the final testing and application of the Eulerian model.

Introduction

In 1980, Congress established the National Acid Precipitation Assessment Program (NAPAP) to coordinate and expand research relevant to the problems posed by acid deposition in and around the United States. The program is organized and managed through 10 subordinate task groups coordinating specific technical areas of research. One of these 10 groups is Task Group B: Man-made Sources, chaired by a representative of the Office of Fossil Energy, Department of Energy. The task group includes members representing the Environmental Protection Agency, the Department of Energy, and the National Laboratory Consortium. The major objectives of Task Group B are to:

1. Provide an accurate and complete inventory of emissions from anthropogenic sources believed to be important in acid deposition processes with adequate geographic, temporal, and sectoral resolution.

2. Provide models which predict how emissions may be altered by factors such as economic growth, fuel supply, emission regulations, and control techniques and which calculate the cost of alternative control strategies.

It is important that all activities related to acid deposition emission inventory development and maintenance be closely coordinated and integrated with other research-oriented inventory efforts and with ongoing emission inventory activities such as those carried out by EPA's Office of Air Quality Planning and Standards (OAQPS) and the Department of Energy.

A coordinated emission inventory plan is developed and revised annually within Task Group B to address the needs of the NAPAP research program. Each of the following 10 NAPAP task groups requires some degree of emission inventory information:

Task Group A: Natural Sources
Task Group B: Man-Made Sources
Task Group C: Atmospheric Processes
Task Group D: Deposition Monitoring
Task Group E: Aquatic Effects
Task Group F: Terrestrial Effects
Task Group G: Materials Effects
Task Group H: Control Technologies
Task Group I: Policy and Assessments
Task Group J: International Activities

Periodic interviews are held with the membership of the task groups to obtain specific inventory needs in terms of pollutants of interest, priorities, and projected milestone dates when inventory data would be

required. From these discussions, two distinct types of inventory development programs can be identified:

- Detailed, multicomponent point and area source disaggregated inventories for defined annual base years to support the development and testing of atmospheric transport and transformation models to predict acid deposition.

- Retrospective inventory summaries of emissions over the past 80 years to support historical analyses for the development of damage functions and the assessment of current damages.

Historic Emissions Inventory[1]

Historic emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) were estimated for Task Group B of the NAPAP for each state in the contiguous United States. Emissions of each pollutant were estimated by source category for every fifth year from 1900 to 1980 and for 1978. Total state emissions were interpolated for the other years based on national consumption levels of fuels. Five-year intervals from 1900 to 1980 were selected to provide an indication of the emission trends sufficient for most effects studies and to develop a methodology that could be applied to all other years. The state level was selected because it provides the most complete and consistent body of information on an historic basis and collectively covers all regions of the country.

Figures 1 and 2 illustrate the overall trend in SO_2 emissions from 1900 to 1980 for the United States by year and by fuel type and source categories, respectively. The source categories used to assemble this national summary included all types of boilers, furnaces, engines, processes, and other anthropogenic emissions. The procedure used for calculating state-level emissions included:

- obtain state-level information on fuel use;

- allocate fuel quantity used by each source category;

- develop source category emissions factors;

- determine fuel sulfur content by state for each category; and

- calculate emissions after emission controls.

The actual procedure varied somewhat depending on the usefulness and availability of information. Figures 3 and 4 illustrate the overall trend in NO_x emissions from 1900 to 1980 for the United States by year and by fuel type and source category, respectively. Today, highway vehicles and electric utilities represent almost equal major contributors to NO_x emissions. Prior to 1920, their combined emissions were insignificant compared to industrial source emissions of NO_x. The NAPAP Historic Emissions Inventory can be evaluated further to provide an indication of seasonal variability in estimated emissions as well as trends in emission patterns as functions of physical stack heights over the calculation period at the state level.

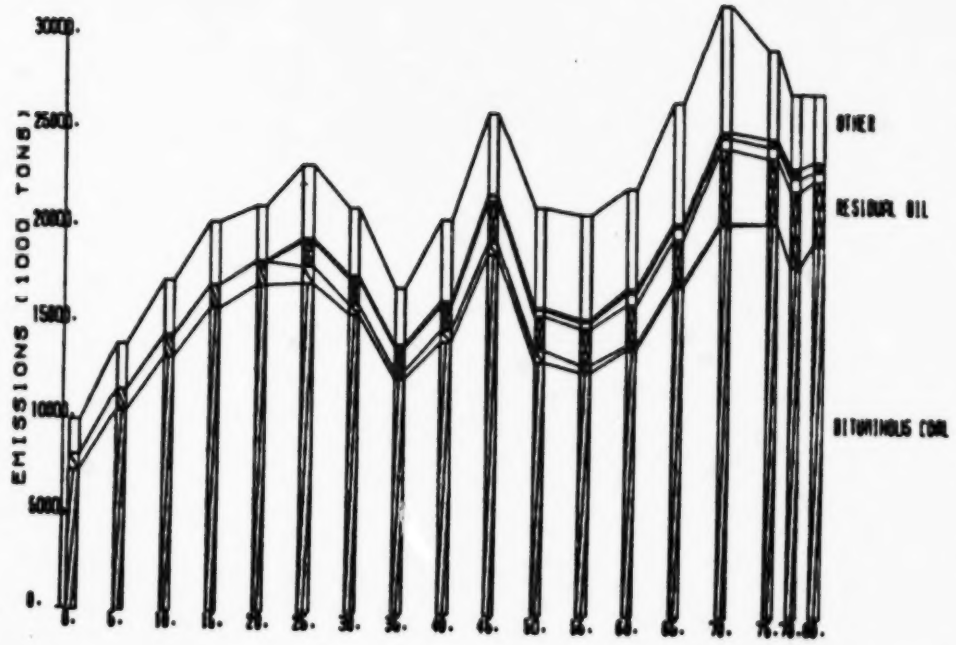

Figure 1. Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by fuel type for each study year.

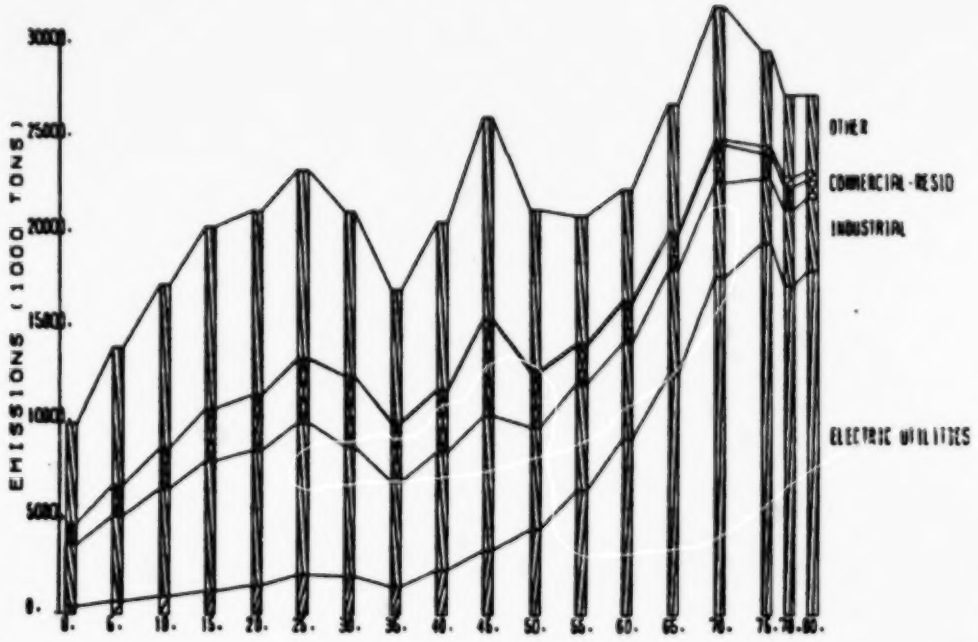

Figure 2. Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by source category for each study year.

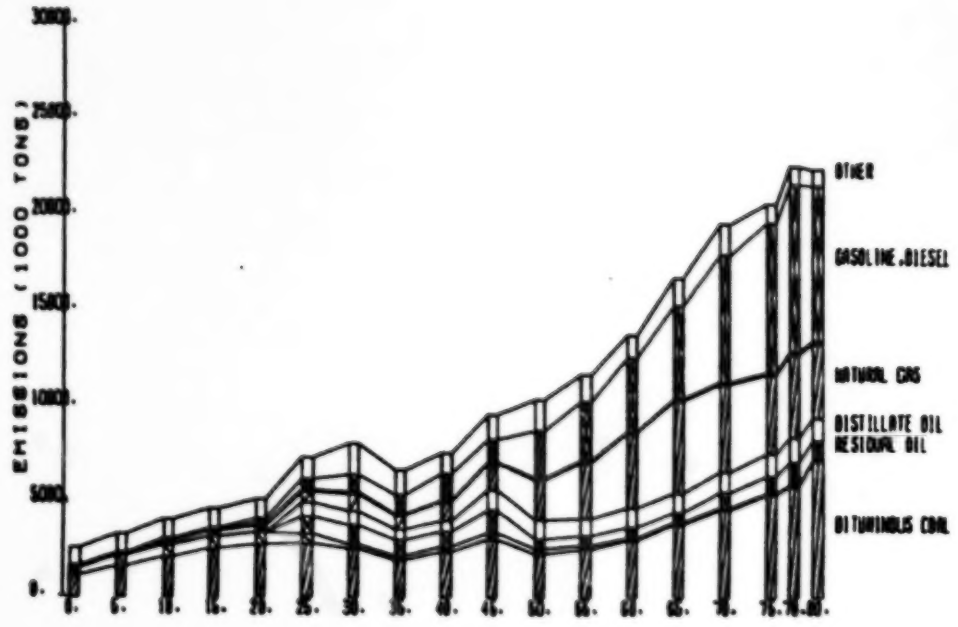

Figure 3. Overall trend in NO_x emissions from 1900 to 1980 for the United States and by fuel type for each study year.

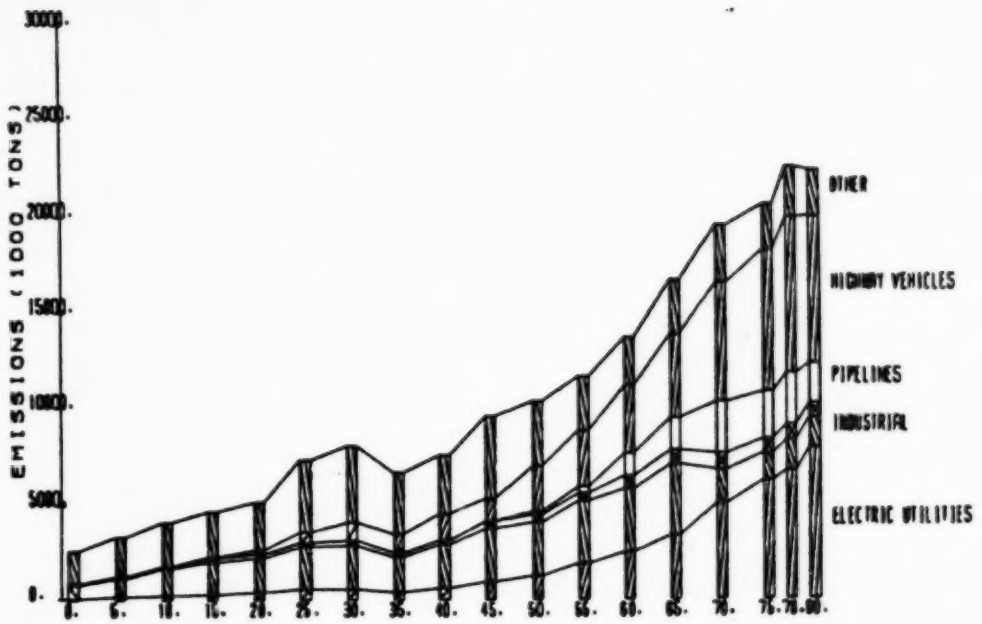

Figure 4. Overall trend in NO_x emissions from 1900 to 1980 for the United States and by source category for each study year.

The 1980 NAPAP Emission Inventory[2]

The current inventory contains point source data for 50,200 plants with over 201,000 emission points and area source data for the 3,069 counties in the contiguous United States, including the District of Columbia. Emissions of SO_2, NO_x, VOC, sulfates, NH_3, CO, and particulate matter are included in the inventory.

The starting point for the 1980 NAPAP data based was the 1980 "snapshot" data file of the National Emissions Data System (NEDS), maintained by the EPA at Research Triangle Park, North Carolina. NEDS contains point source data for major stationary sources of air pollution, as reported to EPA by state air pollution control agencies, and county-level area source data, as estimated by EPA based on published references and other statistical information. The area source emissions account for all mobile sources and small stationary sources not included in the point source file so as to give a complete accounting of total emissions from all sources.

Quality assurance activities for point sources completed thus far have involved:

- Incorporating the latest available EPA emission factors,
- Substitution of point source data from NEDS files other than the 1980 "snapshot" in order to build a NAPAP data base more representative of 1980,
- Adding county centroid latitude and longitude for point sources with missing UTM coordinates,
- Updating fuel type, quantity and quality data, source classification codes, control equipment and efficiency, seasonal throughput, and SO_2 emissions data for electric utilities based on data files compiled by E.H. Pechan and Associates from DOE data sources,
- Comparison of summarized NAPAP emission estimates with similar data compiled previously by Work Group 3B under the U.S.-Canada Memorandum of Intent on transboundary Air Pollution, and
- Substitution of non-utility point source data for 15 northeastern states, based on data compiled for the Northeast Corridor Regional Modeling Project (NECRMP).

A summary of SO_2, NO_x, and VOC emissions by state for the 1980 NAPAP inventory is given in Table I. Statewide emissions are divided into point and area source components to illustrate their relative contribution to total emissions of each pollutant. States with the greatest SO_2 emissions are Ohio, Pennsylvania, and Indiana. States with the greatest NO_x emissions are Texas, California, and Ohio. VOC emissions are dominated by Texas and California.

Table 1. Summary of 1980 NAPAP Emissions by State
(10^3 tons/year)

State	SO_2			NO_x			VOC		
	Point	Area	Total	Point	Area	Total	Point	Area	Total
Alabama	774	76	850	273	252	525	73	351	424
Arizona	824	20	844	141	153	294	13	228	241
Arkansas	59	30	89	65	167	232	14	230	244
California	416	118	534	455	868	1,323	417	1,691	2,108
Colorado	114	20	134	137	155	292	21	300	321
Connecticut	51	18	69	41	103	144	44	259	303
Delaware	105	22	127	36	33	69	26	48	74
Dist. of Col.	11	6	17	5	22	27	1	43	44
Florida	1,124	78	1,202	246	383	629	23	725	748
Georgia	847	30	877	279	308	587	28	495	523
Idaho	36	20	56	9	82	91	6	205	211
Illinois	1,360	99	1,459	655	462	1,117	208	768	976
Indiana	1,746	134	1,880	536	324	860	117	472	589
Iowa	366	24	390	167	182	349	31	241	272
Kansas	198	33	231	302	290	592	81	241	322
Kentucky	1,113	45	1,158	373	231	604	125	280	405
Louisiana	343	158	501	568	253	821	322	299	621
Maine	122	12	134	21	43	64	20	73	93
Maryland	273	23	296	114	164	278	76	270	346
Massachusetts	317	45	362	88	184	272	108	444	552
Michigan	844	34	878	378	368	746	238	730	968
Minnesota	242	21	263	229	227	456	63	360	423
Mississippi	256	50	306	99	196	295	52	234	286
Missouri	1,236	61	1,297	349	258	607	177	429	606
Montana	146	22	168	28	102	130	12	203	215
Nebraska	65	12	77	92	118	210	46	119	165
Nevada	140	7	147	76	47	123	4	73	77
New Hampshire	102	5	107	30	30	60	20	69	89
New Jersey	234	69	303	160	274	434	155	562	717
New Mexico	247	11	258	224	83	307	52	109	161
New York	787	77	864	321	427	748	143	988	1,131
North Carolina	621	32	653	302	268	570	108	465	573
North Dakota	95	19	114	103	65	168	2	46	48
Ohio	2,655	50	2,705	665	554	1,219	165	914	1,079
Oklahoma	86	16	102	177	285	462	72	297	369
Oregon	31	25	56	53	175	228	40	279	319
Pennsylvania	1,770	82	1,852	595	487	1,082	240	802	1,042
Rhode Island	10	4	14	6	30	36	13	84	97
South Carolina	324	18	342	154	148	302	228	259	487
South Dakota	34	7	41	22	55	77	3	88	91
Tennessee	1,103	31	1,134	336	237	573	157	353	510
Texas	1,081	260	1,341	1,543	1,943	3,486	940	1,710	2,650
Utah	89	27	116	80	95	175	11	134	145
Vermont	3	7	10	1	43	44	4	36	40
Virginia	338	48	386	160	251	411	105	358	463
Washington	280	46	326	131	219	350	48	373	421
West Virginia	1,091	13	1,104	352	121	473	14	124	138
Wisconsin	668	20	688	205	221	426	76	372	448
Wyoming	224	25	249	184	115	299	20	74	94
Totals	25,001	2,110	27,111	11,566	12,101	23,667	4,962	18,307	23,269

Data from the 1980 NAPAP emission inventory show that SO_2 emissions are dominated by electric utilities, primarily from coal-fired power plants located in the eastern United States. For NO_x, the largest sources are transportation (mostly highway vehicles), electric utilities, and industrial combustion. For VOC, emissions result largely from transportation (again, primarily highway vehicles), other industrial processes, and miscellaneous sources which include organic solvent use not accounted for by point sources, retail gasoline service stations, and forest wildfires.

The geographic breakdown of SO_2 emissions in NAPAP indicates that EPA Regions 4 and 5 are the largest contributors. The eastern 31 states account for over 82 percent of nationwide SO_2 emissions. For NO_x, Regions 4, 5, and 6 are the highest emitters, with the eastern 31 states accounting for about 64 percent of national emissions. Regions 4, 5, and 6 are also responsible for the greatest amount of VOC emissions. The eastern 31 states account for 66 percent of the nation's VOC emissions.

The relative importance of point versus area source emissions varies for each of the three pollutants. Point sources contribute over 90 percent of national SO_2 emissions. For NO_x, emissions are nearly evenly distributed. Area sources, on the other hand, emit almost 80 percent of total VOC emissions.

Analysis of stack height data shows that nearly all VOC emissions (both point and area sources) are emitted below 36.6 meters. Over 66 percent of the total emissions of NO_x also are released below 36.6 meters. On the other hand, nearly 40 percent of all SO_2 is emitted at heights above 146.3 meters.

County emission densities were calculated and density ranges summarized to obtain more information on the concentration of emissions. For SO_2, counties in the highest emission density range result from power plants located in the East, primarily in the Ohio Valley and Great Lakes areas. These counties represent only 4 percent of those in the nation but have 54 percent of the total emissions. For NO_x, the counties in the highest range result from either power plants or highway vehicles. These counties represent only 3 percent of those in the nation but contribute 27 percent of the total emissions. For VOC, the counties in the highest range result from solvent use and highway vehicles. These counties represent only 2 percent of all counties in the nation but contribute 29 percent of the total emissions.

The current version of the 1980 NAPAP emission inventory represents a detailed inventory of emissions on a national scale. Over 80 percent of the NAPAP emissions truly represent 1980. Over 90 percent are in the range from 1978 to 1981. Many of these large emitting facilities are electric utility plants and nonferrous smelters for which extensive quality assurance efforts have already been performed. About 80 percent of point source SO_2 and NO_x emissions occur at sources with complete stack data and valid UTM coordinates. Currently, emphasis is

being placed on speciation of VOC and NO_x emissions, hourly temporal resolution of emissions, and spatial resolution of data into small 20 km x 20 km grid zones covering the entire United States. Other ongoing activities include incorporation of emission data for Canada into NAPAP, and a statistical evaluation of the uncertainty of NAPAP emission estimates.

The NAPAP 1985 Emission Inventory

The historical and 1980 emission inventory activities have identified the need for an improved data base for current acid deposition assessment activities. In order to fulfill this ultimate objective, a 1985 base year emission inventory will be developed by Task Group B activities. Efforts are being planned to address many of the shortcomings of previous emission inventories.

The development of the 1985 NAPAP inventory will be considered by the EPA as a priority activity for the state agencies. The EPA will initiate the development of standardized procedures for estimating emissions for all sources. Workshops will be held with EPA Regional Office staff and state agency personnel to explain the inventory development process and provide the protocols for data gathering. The inventory development plan for 1985 will include an expansion of QA/QC edit checks. Further, the EPA will request major source emitters and the corresponding states to review and confirm the relevant estimates contained in the inventory.

Since electric utilities represent a significant portion of SO_2 and NO_x emissions, Task Group B activities must ensure that high quality emissions data are available for this sector for the 1985 inventory. Data can be gathered from the NEDS data submitted by state agencies or from information supplied by utility companies to the Department of Energy. Both data sources will be used to ensure that the best possible data are available for this source category.

Figure 5 depicts the interrelationshps of activities designed to produce the 1985 emission inventory which will be stored in Emission Inventory System (EIS) point source (PS) and area source (AS) formats . A major activity in the inventory development will be the formulation of detailed allocation factors for SO_2, NO_x, and all VOC species required for the Eulerian model. The 1985 inventory will contain 23 pollutants:

1. SO_2
2. NO^2
3. NO_2
4. primary sulfate
5. CO
6. total suspended particulate
7. alkaline dust
8. ammonia
9. HF
10. HCl
11. alkanes
12. methane
13. alkenes
14. propylene
15. aldehydes
16. formaldehyde
17. organic acids
18. formic acid
19. propane
20. butane
21. aromatics
22. benzene
23. acetic acid

Calculations will be performed on the 1985 NAPAP inventory to determine the uncertainty of the estimates. The calculation of the uncertainty of the emission values will be based on the statistical

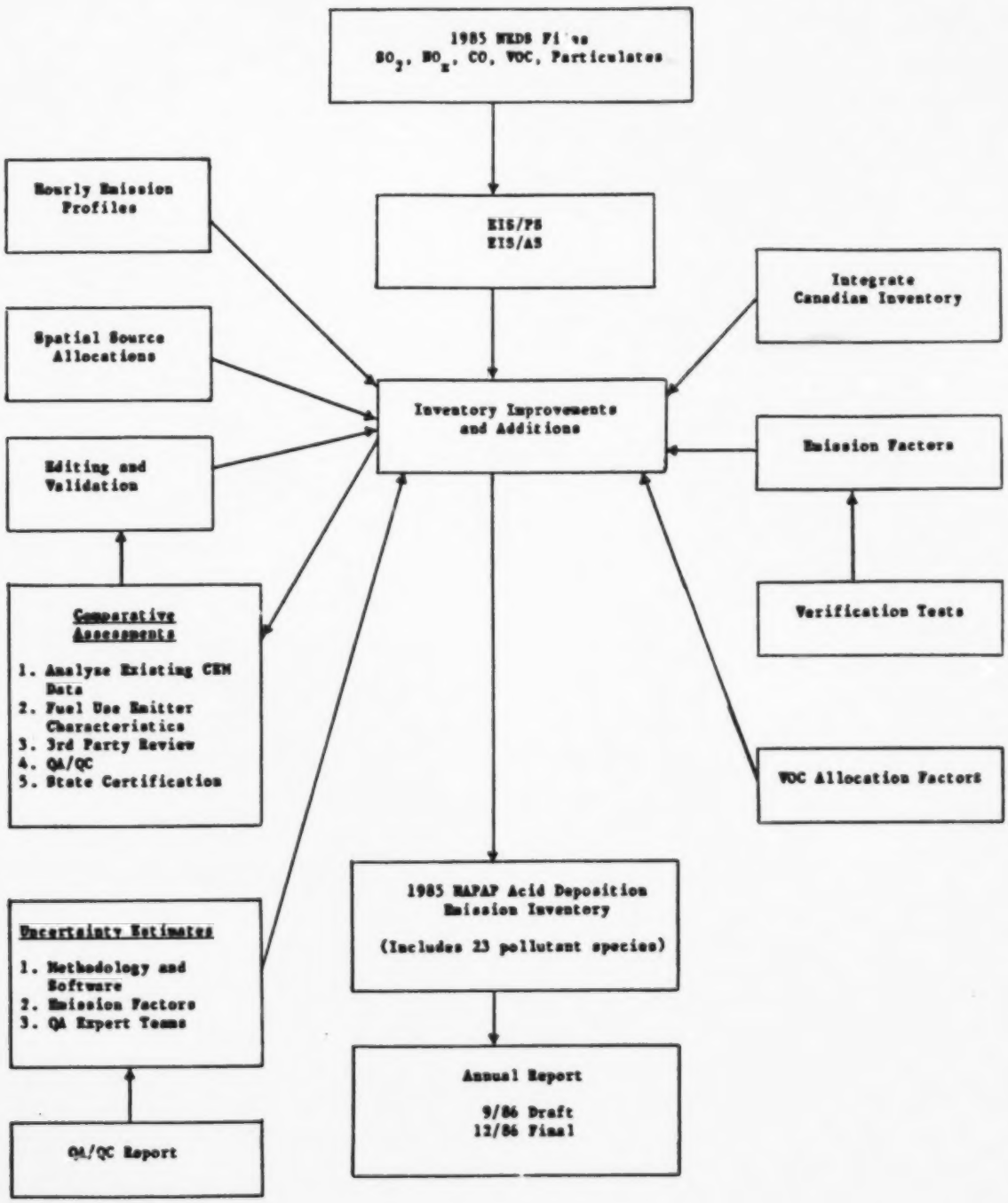

Figure 5. Integration of activities for developing the 1985 emission inventory.

formulas expressing the variance of a function based on the expected values and variances of the parameters used to calculate the function. Application of these techniques will start with the algorithms used to calculate the yearly emission values and will be extended to include currently known algorithms for spatial and temporal aggregation and spatial, temporal, and species disaggregation as applicable.

Summary

The emission inventory development activities within NAPAP Task Group B have addressed the formulation of complex and detailed data bases for numerous applications within the technical and administrative communities addressing acid deposition research and assessments. Both preliminary and final NAPAP 1980 base year inventories have been supplied to assist in the refinement of the atmospheric transport, transformation, and deposition model. A detailed historic emission inventory for SO_2 and NO_x has been prepared for the period from 1900 to 1980. This computerized data base has found application for research use by several NAPAP task groups studying long-term trends and for the preparation of assessments. The present and near-term research activities within Task Group B are directed to the development of a highly resolved 1985 base year NAPAP inventory with desired species, temporal, and sectoral resolution to drive the final iteration of the Eulerian Regional Acid Deposition Model. Major tasks include expansion of the required inventory data handling system, development of detailed VOC emission factors, and development/implementation of appropriate QA/QC review and assessment of the accuracy of the final inventory.

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2. D.A. Toothman, J.C. Yates, and E.J. Sabo, "Status Report on the Development of the NAPAP Emission Inventory for the 1980 Base Year and Summary of Preliminary Data," U.S. Environmental Protection Agency, EPA-600/7-84-091 (NTIS PB85-167930), Research Triangle Park, NC, December 1984.

Note: To convert from English to metric units, use the following conversion factor: 1 short ton = 1.0025 metric tons.